1400 W. OLYMPIC BLVD.
LOS ANGELES 15, CALIF.

1110

FREED No. 1110-A and No. 1110-AB
INCREMENTAL
INDUCTANCE BRIDGE

INSTRUCTION MANUAL

FREED TRANSFORMER CO., INC.
1718 WEIRFIELD ST., BROOKLYN (RIDGEWOOD) 27, N. Y.

FREED No. 1110-A and No. 1110-AB
INCREMENTAL
INDUCTANCE BRIDGE

WESTERN SCIENTIFIC INSTRUMENT CO.
SOUTHERN CALIFORNIA OFFICE
1200 W. OLYMPIC BLVD.
LOS ANGELES 15, CALIF.

FREED No. 1110-A and No. 1110-AB
INCREMENTAL
INDUCTANCE BRIDGE

The Incremental Inductance Bridge is designed for measuring the inductance of Iron Core components at any frequency up to 10,000 cycles. Inductors can be measured with a superimposed direct current, therefore, the bridge will measure the incremental inductance of coils. The bridge can be used for determination of storage factor, "Q", either at a given frequency in function of the applied voltage or at a given voltage in function of the applied frequency. The bridge can be used by the manufacturers of iron core components, for testing filter chokes, high Q coils, and iron core audio and supersonic frequency components. Due to its very wide inductance range the instrument can be used as a general purpose laboratory inductance bridge.

INDUCTANCE RANGE

One millihenry to one thousand henries in five ranges. Inductance values are read directly from a four dial decade and multiplier switch. The last range may be extended to 10,000 henries through the use of an external resistance decade.

CONDUCTANCE RANGE

One micromho to one mho in five ranges, read directly from a four dial decade and multiplier switch. This conductance represents the reciprocal of the A.C. resistance of the coil.

"Q" RANGE

"Q" is measured as the product of Inductive reactance (L ω) and Conductance (G). The range of "Q" measured on this bridge is .5 to 100. Measurement of inductance is independent of the values of "Q".

ACCURACY

The accuracy of the instrument is 1% and is calibrated at both 60 cycles and 1KC on the .01, .1 and 1 henry range. The 10 and 100 henry ranges are calibrated only at 60 cycles since resonance effects will give an erroneous reading when measuring inductors over 1 henry at a higher frequency.

1% UP TO 1500Ω ON 10 RANGE.
1% " 400Ω ON 100 "

FOR 1110AB ← SEE PG 7+8

RANGE OF SUPERIMPOSED D.C.

On multiplier switch position L x 100, the D.C. is limited to 10 Ma.

On the position L x 10, the D.C. is limited to 250 Ma.

On all other positions, the D.C. can be one ampere maximum.

When using R dial the current is limited to 1 amp on the 100 ohm position, 250 Ma. on the 1000 ohm position, and 10 Ma. on the 10,000 ohm position.

TEMPERATURE AND HUMIDITY EFFECTS

The readings of the bridge are unaffected by normal temperature and humidity variations.

GENERAL OPERATING PROCEDURE

An A.C. source* is connected to the terminals marked "AC". A suitable null detector* is connected to the terminals marked "AMP". The unknown inductance is connected to either set of terminals marked "LX". The extra set of terminals is provided for convenient measurement of the voltage across the unknown inductance.

If D.C. is desired in the coil a D.C. source* is connected to the terminals marked "D.C.", and toggle switch marked "DC" set to "ON" position. The D.C. source is in series with the A.C. supply therefore it must have a low internal impedance. This may be obtained by shunting the DC terminals with an 8 mfd. electrolytic condenser, observing proper polarity.

The terminals marked "SERIES RES" are used when it is desired to extend the range of inductance above 1000 henries, the multiplier switch is set in the L x 100 position and a resistance decade of 10 x 10,000 is connected, thereby producing an additional dial reading of 10 x 10 henries. Normally, however, the terminals are shorted with the shorting link provided.

*Suitable Equipment for use with the Inductance Bridge.

Freed Type 1140-A Null Detector
Freed Type 1210-A Null Detector and Vacuum Tube Voltmeter
Freed Type 1170-A Variable D.C. Power Supply
Freed Type 1180 Variable A.C. Power Supply

The dial "R" is used when it is desired to extend the conductance range of the bridge when measuring high "Q" coils. A 100, 1000, or 10,000 ohm resistor may be placed in series with the coil under test. Normally, however, the dial should be set at zero.

STEPS IN MEASUREMENT:

1. Set the multiplier switch to the desired range. Set the 1000/step "G" dial to maximum (10 x 1000/step position). Set "L" and "R" dials to zero.

2. Starting with the "L" dials, adjust for an indication on the null detector then alternately adjust the "L" and "G" dials until a minimum indication is obtained. When the resistive component balance cannot be obtained with all the "G" dials at maximum a resistance has to be inserted in series with the coil. This is accomplished by setting the "R" dial at 100, 1000 or 10,000 ohms. Since a resistance in series with the coil will effect both the A.C. voltage across the coil and the D.C. current through the coil, the "R" dial must be set to the minimum resistance value, i.e., if "G" balance can be obtained with R set to 100, the 1000 ohm setting should not be used.

NOTE 1: Do not switch the "R" dial when D.C. is on.

NOTE 2: The resistance of the S arm will change if the unknown is tested with a high DC current. This change of resistance may be compensated for by use of the correction factors below. The figures in column (1) apply when the DC current has been flowing for 5 minutes and the figures in column (2) after 15 minutes.

Multiplier Switch Position	Current (Ma DC)	Multiply Reading By (1)	(2)
L x .01 and .1	500	1.003	1.004
	1000	1.006	1.007
L x 1	500	1.005	1.008
	1000	1.008	1.010
L x 10	100	1.010	1.012
	250	1.019	1.022

3. Read the unknown inductance by multiplying the "L" dial reading by the "L" multiplier (M_L) shown on the pushbutton switch.

$$L_X = M_L \times L \quad (\text{EQ. 1, FIG. 1})$$

4. Read the unknown conductance by multiplying the "G" dial reading by the "G" multiplier (M_G) on pushbutton switch.

$$G_X = M_G \times G; \; R_X = \frac{1}{M_G G} \text{ FOR "R" O POSITION.}$$

EQ. 2, FIG. 1

$$R_X = \left(\frac{1}{M_G G}\right) - R \quad \text{FOR "R" 100, 1000, 10,000 } \Omega \text{ POSITION.}$$

5. The "Q" of coil is given by:

$$Q = \frac{L \times \omega}{R_X}$$

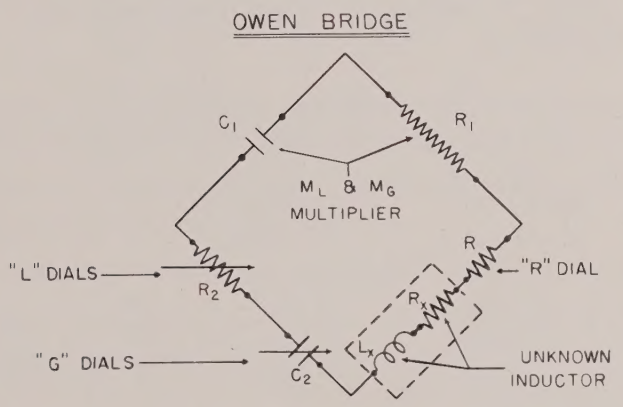


FIG. #1

$$L_X = R_1 C_1 \times R_2 \text{ ----------(1)}$$

$$G_X = \frac{1}{R_X + R} = \frac{1}{R_1 C_1} \times C_2 \text{ ---(2)}$$

$$R_X = \frac{1}{G_X} - R \text{ ----------(2A)}$$

(See appendix for derivations)

R_2 is composed of four resistance decades calibrated in henries - 10 x 1, 10 x .1, 10 x .01, 10 x .001. This corresponds to the four "L" dials.

C_2 is composed of four capacitance decades calibrated in micromhos - 10 x 1000, 10 x 100, 10 x 10, 10 x 1. This corresponds to the four "G" dials.

$R_1 C_1$ is the inductance multiplier M_L

$\frac{1}{R_1 C_1}$ is the conductance multiplier M_G

These multipliers are determined by the position of the push button switch. The total range of these multipliers is from 100 to .01.

TO TEST WITH LARGE VALUE OF DC CURRENT

The D.C. current that may be applied to the coil under test is limited by the current handling ability of the R1 arm since condensers block the D.C. from all other bridge components. When the L Multiplier is in the .01, .1 and 1 position one ampere D.C. may be applied to the coil under test. This covers an inductance range of 1 mh to 11.11 henry and can be extended to 111.11 henries by inserting a 10K ohm/step in the "Series R" terminals. The Freed 1420 Decade Resistor is available for this application. This will read 10h/step.

When the L multiplier is in the X10 position the DC is limited to 250 ma. This range allows inductors of 111.1 henries to be measured with 250 ma. D.C. To measure larger inductances use 10K/step decade as outlined above.

Chart #1 indicates the maximum allowable D.C. on each range and the extended range when using the 10K ohm resistor as outlined above.

Multiplier	Max. DC Current	Inductance Range	*Extended Inductance Range
L x .01	1 amp	1 mh - 110 mh	1 mh - 1.11 h
L x .1	1 amp	10 mh - 1.11 h	10 mh - 11.1 h
L x 1	1 amp	100 mh - 11.1 h	100 mh - 111 h
L x 10	250 ma	1 h - 111 h	1 h - 1110 h
L x 100	10 ma	10 h - 1110 h	10 h - 11,100 h

CHART #1

INDUCTANCE MEASUREMENTS USING HIGHER AC TEST POTENTIALS

From Fig. #1 we note that any AC voltage impressed across the coil under test is also across R2. The wattage rating of these decade resistors is 2 watts per-step so that the permissible AC voltage across the test coil is dependent only on the position of the L dials. The maximum permissible AC voltages are given in Chart #2. It should be remembered that because of the overlap of ranges a 1 henry inductor may be measured with 280 volts across the coil. This is accomplished by using the L multiplier in the .1 position and having the L dials on 10. The series decade (1420) as outlined under DC measurements may also be used when it is necessary to have more than 100 volts across the inductor and the dial is in position 1 or 2.

Maximum safe A.C. voltage that can be applied to the INCREMENTAL INDUCTANCE BRIDGE at both 60 and 400 cps.

WHEN VALUE OF INDUCTOR IS READ ON:

1H/STEP DIAL

Dial Position	Voltage Fed into Bridge
1	70 volts
2	140 volts
3	210 volts
4	280 volts
5	280 volts
6	280 volts
7	280 volts
8	280 volts
9	280 volts
10	280 volts

.1H/STEP DIAL

Dial Position	Voltage Fed into Bridge
1	22 volts
2	44 volts
3	66 volts
4	88 volts
5	88 volts
6	88 volts
7	88 volts
8	88 volts
9	88 volts
10	88 volts

If both decades are used, the maximum voltage may not exceed the sum of the two individual voltages.

CHART #2

MEASURING LARGE INDUCTORS

To measure inductors above 1 henry at a test frequency above 1KC calls for special precautions. In general if $\sqrt{LMAX} = \frac{1000}{\text{frequency}}$ the errors due to stray capacity are less than 1%. If this value is exceeded large errors may result since the resonant condition of the coil is approached. The stray capacity of the coil, the bridge and the VTVM across it are all in parallel and may be of the order of 1000 mmfd. The bridge capacity is approximately 150 mmfd. and the Freed 1210-A VTVM input is less than 25 mmfd. See appendix for a discussion of this problem.

A compensated bridge for measuring larger inductors, the Freed 1110-AB is available and chart #3 indicates the maximum inductance that may be measured accurately at the various test frequencies.

SUPPLEMENTARY INSTRUCTIONS FOR 1110-AB

From Appendix, Page 10, we note that the upper frequency limit for measuring inductors is determined by the stray capacity of the test coil as well as the bridge. The capacities in the 1110-AB have been reduced so that the range is extended as shown in Chart #3, Page 7.

Comparison of

Inductance VS. Maximum Frequency
1110-A and 1110-AB Bridges

	MAXIMUM FREQUENCY	
L in Henries	Type 1110-A	Type 1110-AB
.01-0.1	10KC	10KC
1	1KC	5KC
10	300 cps	1500 cps
100	100 cps	400 cps

CHART #3

In the "1" position the bridge is identical to the 1110-A. In the "2" position the Lx terminals have been placed above ground to reduce the stray capacities. Placing a voltmeter across these terminals will add capacity thus giving erroneous readings.

From Fig. #5 we see that the impedance of the unknown is large compared to the "S" arm so that almost the total input voltage to the bridge is dropped across the Lx terminals. Therefore the AC input voltage to the bridge should be measured. For direct measurement of voltage across Lx terminals, connect an ungrounded VTVM and remove it before the final balance is obtained. All other procedures and instructions are the same as for the 1110-A.

CAUTION: Observe proper polarity when connecting Null Detector and VTVM.

SOURCES OF ERROR
Distributed Capacity

If the test coil has a large number of turns as is usually the case for large inductors, an apparent inductance L^1 will be measured.

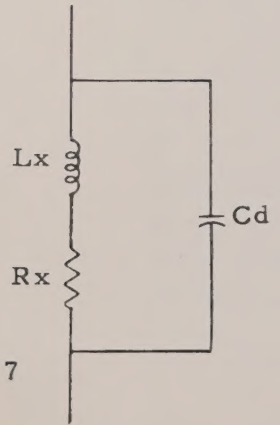
$$Z = \frac{Rx + j\omega\,[L\,x\,(1 - \omega^2\,Lx\,Cd) - CR^2]}{(1 - \omega^2 Cd\,Lx)^2 + \omega^2 Cd^2\,Rx^2}$$

Neglecting the smaller terms
CR^2 & $\omega^2 C^2 R^2$

$$Z = \frac{Rx + j\omega Lx(1 - \omega^2 Lx\,Cd)}{(1 - \omega^2 Lx\,Cd)^2}$$

$$R^1 = \frac{Rx}{(1 - \omega^2\,Lx\,Cd)^2}$$

$$L^1 = \frac{Lx}{1 - \omega^2 Lx\,Cd}$$



Lx = Inductance of Coil
L^1 = Apparent Inductance of Coil
Rx = Resistance of Coil
R^1 = Apparent Resistance of Coil
Cs = Stray Capacities

It should be noted that to keep errors in L within

$$1\% - \sqrt{L\ Max.} = \frac{1000}{Freq.} \text{ for 1110-A and}$$

$$\sqrt{L\ Max.} = \frac{4500}{Freq.} \text{ for 1110-AB} \longrightarrow L_{MAX} = 145$$

The error in R however is much larger as can be seen from the above.

CALIBRATION PROCEDURE FOR 1110-A INDUCTANCE BRIDGE

1. To calibrate the 1110-A Inductance Bridge connect a standard inductor across the Lx terminals and obtain an inductance reading. If this reading is off, either the L decades or S multiplier are damaged. The L decades are composed of precision $\pm 1/10\%$ resistors and under normal use will not change. They may be checked with a Wheatstone Bridge.

2. Connect a Standard .01 henry inductor across the "Lx" terminals and follow the procedure as outlined in the instruction book to obtain a reading. The L multiplier should be in the .01 position and the "R" dial on 0. Record this reading.

3. Repeat step 2 using a .1 henry inductor.

4. If both readings are off the 10 ohm resistor in S arm must be adjusted. A space is provided on the back of the L multiplier switch where a shunting resistor can be mounted.

5. To determine the value of the shunting resistor use the following formula

$$R = \frac{Ls \times S}{Ls - Lx}$$

Ls = Value of Standard Inductor
Lx = Measured Value of Standard Inductor
S = Setting of L Multiplier

6. If either reading on .1 or .01 henry range is off, but not both, the Standard Condenser should be adjusted.

7. Next repeat step 2 using 1, 10 and 100 henry Standard and follow adjustment procedure as outlined under step 4.

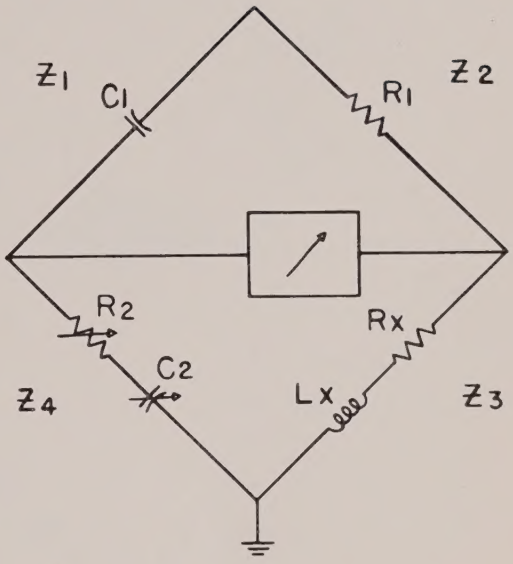
NOTE: The condenser affects all of the higher 4 ranges, so that this should not be changed unless the indicated inductance reading on all 4 ranges is high.

8. To check "G" dials open "Series R" link and place L decades on zero. Then check capacity from lower terminal of "Series R" link to ground. The 1000 μmho/step dial is a 1 mfd/step decade. 100 μmho. is .1 mfd/step etc.

1. – AT BALANCE –

$$\frac{Z_1}{Z_4} = \frac{Z_2}{Z_3}, \quad Z_3 = \frac{Z_2 Z_4}{Z_1} \text{ OR}$$

$$j\omega Lx + Rx = \frac{R_1\left(\frac{1}{j\omega C_2} + R_2\right)}{\frac{1}{j\omega C_1}}$$



$$Rx + j\omega Lx = \frac{R_1 + j\omega C_2 R_2 R_1}{\frac{C_2}{C_1}} \qquad \frac{R_1 C_1}{C_2} + j\omega C_1 R_1 R_2$$

2. $$Rx + j\omega Lx = \frac{R_1 C_1}{C_2} + j\omega C_1 R_1 R_2$$

FROM 2 WE SEE

$$Rx = \frac{R_1 C_1}{C_2} \quad \text{EQ. 1 FIG. 1}$$

$$Lx = R_1 C_1 R_2 \quad \text{EQ. 2 FIG. 1}$$

INDUCTANCE BRIDGE FREED #1110-AB

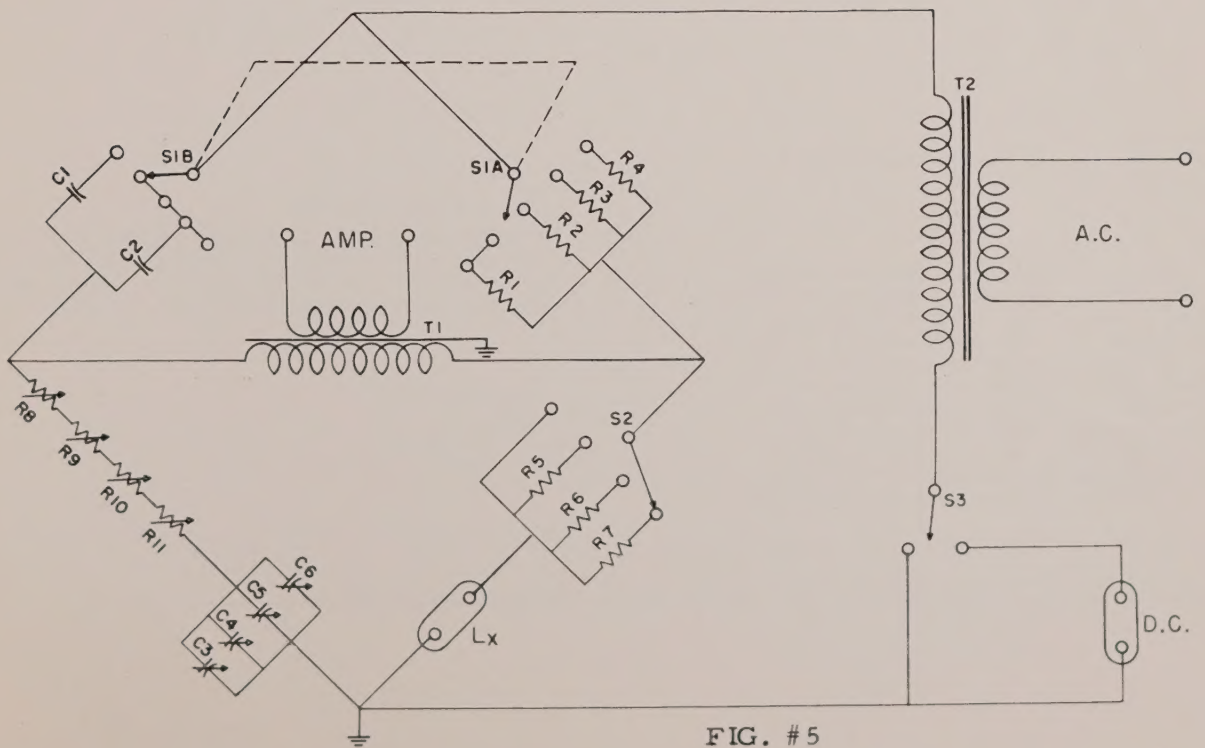


FIG. #5

INDUCTANCE BRIDGE FREED #1110-AB

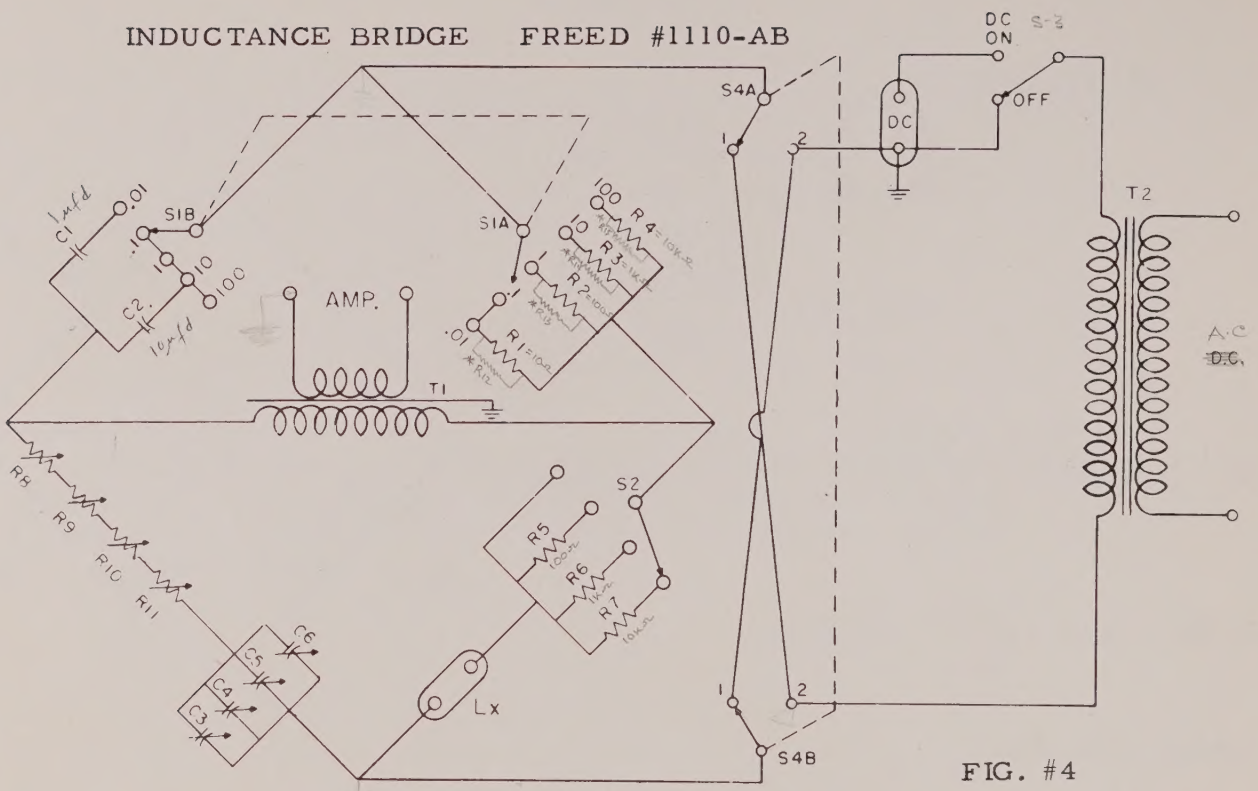


FIG. #4

PARTS LIST FOR 1110-A and 1110-AB

INCREMENTAL INDUCTANCE BRIDGE

See FIG. 4

Transformers

T- 1	Freed # 24974	Shielded isolation transformer
T- 2	Freed # 16563	

Resistors

R- 1	10 ohms	160 watt non inductive resistor
R- 2	100 ohms	100 watt non inductive resistor
R- 3	1000 ohms	50 watt non inductive resistor
R- 4	10000 ohms	10 watt non inductive resistor
R- 5	100 ohms	100 watt non inductive resistor
R- 6	1000 ohms	50 watt non inductive resistor
R- 7	10000 ohms	10 watt non inductive resistor
R- 8	1000 ohm/step decade marked 10 x 1 L dial	
R- 9	100 ohm/step decade marked 10 x .1 L dial	
R-10	10 ohm/step decade marked 10 x .01 L dial	
R-11	1 ohm/step decade marked 10 x .001 L dial	

R-12, R-13, R-14, R-15 } CALIBRATION RESISTORS FOR L MULTIPLIER RANGES - ADJUSTED AS REQUIRED BY WSFG. L.C. } THESE ARE THE FOUR, 1WATT, COMPOSITION RESISTORS FOUND ON THE BACK OF THE MULTIPLIER PUSH BUTTON SWITCH.

Capacitors

C-1	1 mfd	Dual ratio capacitors
C-2	10 mfd	Dual ratio capacitors
C-3	1 mfd/step decade condenser marked 10 x	1000 micromho
C-4	.1 mfd/step decade condenser marked 10 x	100 micromho
C-5	.01 mfd/step decade condenser marked 10 x	10 micromho
C-6	.001 mfd/step decade condenser marked 10 x	1 micromho

Switches

S-1	L	Multiplier switch
S-2	R	Dial
S-3	DC ON-OFF switch	
S-4	Bridge switch	